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Defining the knee joint flexion–extension axis for purposes of quantitative gait analysis: An evaluation of methods

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Abstract

Minimising measurement variability associated with hip axial rotation and avoiding knee joint angle cross-talk are two fundamental objectives of any method used to define the knee joint flexion–extension axis for purposes of quantitative gait analysis. The aim of this experiment was to compare three different methods of defining this axis: the knee alignment device (KAD) method, a method based on the transepicondylar axis (TEA) and an alternative numerical method (Dynamic). The former two methods are common approaches that have been applied clinically in many quantitative gait analysis laboratories; the latter is an optimisation procedure. A cohort of 20 subjects performed three different functional tasks (normal gait; squat; non-weight bearing knee flexion) on repeated occasions. Three-dimensional hip and knee angles were computed using the three alternative methods of defining the knee joint flexion–extension axis. The repeatability of hip axial rotation measurements during normal gait was found to be significantly better for the Dynamic method ($p < 0.01$). Furthermore, both the variance in the knee varus–valgus kinematic profile and the degree of knee joint angle cross-talk were smallest for the Dynamic method across all functional tasks. The Dynamic method therefore provided superior results in comparison to the KAD and TEA-based methods and thus represents an attractive solution for orientating the knee joint flexion–extension axis for purposes of quantitative gait analysis.

Keywords: Gait analysis; Kinematics; Knee; Axis of rotation; Hip rotation

1. Introduction

The definition of a femoral anatomical frame (AF) for the purposes of quantitative gait analysis essentially encompasses two steps. First, the primary axis must be defined. This axis should coincide with the longitudinal axis (knee joint centre (KJC) to hip joint centre (HJC)) for error minimisation [1]. Because of the long and narrow shape of the femur, errors in identifying the proximal and distal landmarks used to define the joint centres, and thus the longitudinal axis, have a minor impact upon the resultant orientation of this axis. Second, the femoral AF frontal plane must be defined based on an optimal estimate of the functional knee joint flexion–extension axis, a procedure that can be prone to considerable error.

The effect that errors in defining the knee joint flexion–extension axis have on the estimation of knee kinematics has been well demonstrated. If the defined knee joint flexion–extension axis is misaligned, errors propagate 'downstream' to the knee varus–valgus and axial rotation angles [2–8]. This is typically described as knee joint angle cross-talk. Whilst such will certainly threaten the repeatability of these angles, a less acknowledged side effect but perhaps one of greater clinical concern is the propagation of errors proximally.

The neutral position of hip axial rotation is dependent upon the orientation of the knee joint flexion–extension axis. Errors in defining this axis manifest as offsets in the hip axial rotation kinematic profile. Thus, errors in defining the knee joint flexion–extension axis can cause considerable variability in

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